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THE UPGRADED SUDBURY LOCAL TELEMETERED NETWORK (SLTN): THE FIRST YEAR OF OPERATION (93-94)

C.J. Pritchard and S. Talebi

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THE UPGRADED SUDBURY LOCAL TELEMETERED NETWORK (SLTN): THE FIRST YEAR OF OPERATION (93 - 94)

BY

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ABSTRACT

The Sudbury Local Telemetered Network (SLTN) was developed as part of the Canada-Ontario-Industry rockburst project ("phase 1", 1985-1990) in order to improve detection and source location capabilities of mine-induced seismic events within the Sudbury basin. This network which became fully operational in 1987, was based on three 1-component short-period seismograph stations located around the rim of the Sudbury basin. During the "phase 2" rockburst project (Canadian Rockburst Research Program, 1990-1995), it was decided to upgrade this network as part of CANMET-MRL's mandate in rockburst monitoring. Installation of the upgraded network started in July 1993 as SLTN data were rerouted to CANMET Sudbury laboratory for processing. A new approach in data acquisition, transfer and processing was incorporated in this upgrade. The upgraded network includes four 1-component seismograph sensors and a triaxial seismograph station. The objectives of the upgrade have been accomplished; i.e. expansion of the network (2 additional seismograph stations), improvements in hardware, software and data quality. The operation of the network over the past year has required a close attention. Further improvements related to the performance of the overall system have been made recently. The results of rockburst detection over the past year are presented in this report.

Résumé

Le réseau local télémétré de Sudbury (SLTN) a été développé dans le cadre du projet de recherche conjoint Canada-Ontario-Industrie sur les coups de toit (phase 1, 1985-1990) avec pour objectif l'amélioration des capacités de détection et de localisation des sources des événements sismiques induits par les mines dans le bassin de Sudbury. Ce réseau qui est devenu opérationnel en 1987, était basé sur trois stations sismographiques courtes périodes, à une composante, placées en bordure du bassin de Sudbury. Au cours de la "phase 2" du projet sur les coups de toit (le projet Canadien sur les coups de toit, 1990-1995), CANMET- LRM a décidé, dans le cadre de son mandat, d'améliorer ce réseau. L'installation du nouveau réseau a commencé en juillet 1993 quand les données du SLTN ont été transmises au laboratoire de CANMET à Sudbury pour analyse. Une nouvelle approche dans l'acquisition, le transfert et le traitement des données a été incorporée dans ce nouveau réseau. Le réseau comporte dorénavant quatre sismographes à une composante et un sismographe à trois composantes. Les objectifs de l'amélioration du réseau sont maintenant atteints; c-à-d. expansion du réseau (2 stations sismographiques supplémentaires), l'amélioration de l'équipement, du logiciel et de la qualité des données. L'opération de ce réseau au cours de l'année passée a nécessité une attention constante. Des améliorations supplémentaires liées à la performance du système dans son ensemble ont été récemment réalisées. Les résultats de détection des coups de toit au cours de l'année passée ont été présentés dans ce rapport.

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1.0 INTRODUCTION

The Sudbury Local Telemetered Network (SLTN) was developed as part of the Canada-Ontario-Industry rockburst project (rockburst project "phase 1", 1985-1990). The main objective of SLTN was to improve detection and source location capabilities for mine-induced seismic events and rockbursts within the Sudbury basin. The original network, which became fully operational in 1987, used three 1-component short-period seismograph stations located around the rim of the basin.

During the "phase 2" rockburst project (Canadian Rockburst Research Program, 1990-1995), the seismograph network operated by CANMET in northern Ontario and northwestern Quebec, of which the SLTN is part, was reviewed and a decision was made to upgrade this network. The main objective of this changeover was to improve the detection capabilities of this network and to make it more efficient. A new approach in data acquisition, transfer and processing was incorporated in this upgrade. Installation of the upgraded network started in July 1993 as SLTN data were rerouted to the CANMET-MRL Sudbury laboratory for processing. The upgraded network includes four 1-component seismograph sensors and a triaxial seismograph station. The present report summarizes the objectives of installation and different components of the upgraded SLTN, a summary of its operations over the past year, results of rockburst monitoring since the upgrade and plans for future expansion of this network.

2.0 BACKGROUND

Most hard-rock mining districts in northern Ontario are located within the seismically stable Precambrian Shield. Because of lack of significant seismicity in this part of the country, coverage of seismic stations has been historically poor, except for one seismograph station installed in Kirkland Lake in the 1940's to record rockburst activity in the local gold mines. The coverage has improved significantly since 1982 when the Canadian Nuclear Fuel Waste Management Program operated by the Atomic Energy of Canada Ltd. supported the operation of six seismograph stations in northern Ontario and Manitoba, to provide data for regional seismic

hazard estimates (figure 1). These stations are part of the Eastern Canada Telemetered Network (ECTN) operated by the Geophysics Division, Geological Survey of Canada (GSC) who operates the Canadian Seismograph Network for earthquake detection across the country. At most stations, only the analog signal used to be recorded on a helicorder, the paper chart being changed once a day (Hedley, 1992).

The Canada-Ontario-Industry rockburst project (Phase 1) was initiated in 1985. One of the first tasks undertaken in this five-year program was to increase the number of seismograph stations around the Sudbury basin from one to three in order to increase the range of recorded events and to provide source location capabilities for some previously unlocated rockbursts. The Sudbury Local Telemetered Network (SLTN) became fully operational in 1987. The original SLTN network provided coverage to the mines within the Sudbury basin and consisted of three stations located around the rim of the basin (figure 2). Seismograph stations were also installed at Elliot Lake, Red Lake and Kirkland Lake (Plouffe et al. 1990). All seismograph stations consist of a vertical single-component, one-second period, Teledyne Geotech S13 seismometer, usually recording in the frequency range 1 to 16 Hz. Seismic signals of SLTN seismographs were digitized at each station and transmitted by dedicated telephone lines to Science North, a public science centre in Sudbury. A processor there saved triggered seismic events and sent them automatically over a dedicated telephone line to GSC in Ottawa where they were processed and catalogued (Hedley, 1992).

Hedley (1992) notes that while in some cases, it is possible to differentiate between rockbursts and blasts, the task is difficult in other cases. Figure 3 shows seismic records for two rockbursts and two blasts recorded on the Elliot Lake seismograph. The distinction between rockbursts and blasts is rather easy at close distances (figures 3a and 3b) because of different signatures produced and the fact that central blasts occur at specific times of each day. At larger distances (figures 3c and 3d) the task becomes more difficult and events have to be confirmed by mine operators. Note also the significant improvement in data quality when analog records such as these are compared to digital records such as those recorded by the upgraded SLTN presented in the next section. Figure 4 shows a histogram of large seismic events (Mn > 2.0) in Sudbury mines over the period 1984-1990.

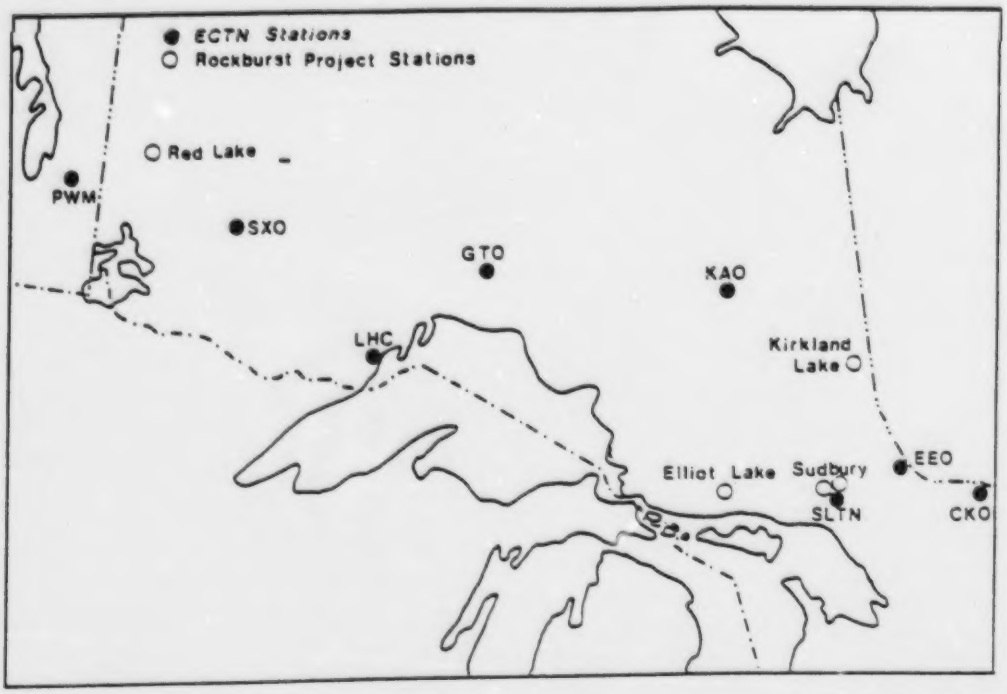


Figure 1 - Location of seismograph stations in northern Ontario (Hedley, 1992).

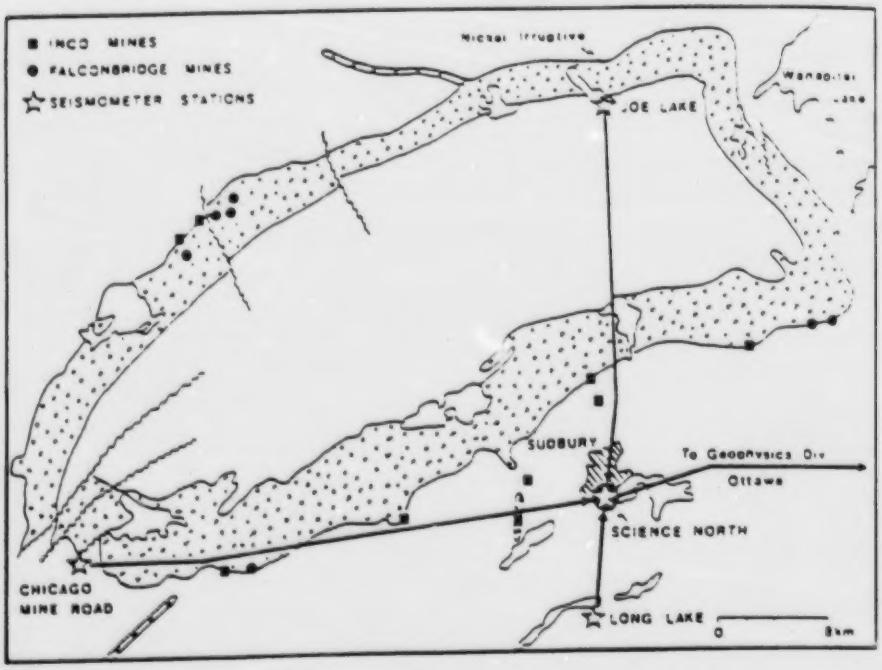
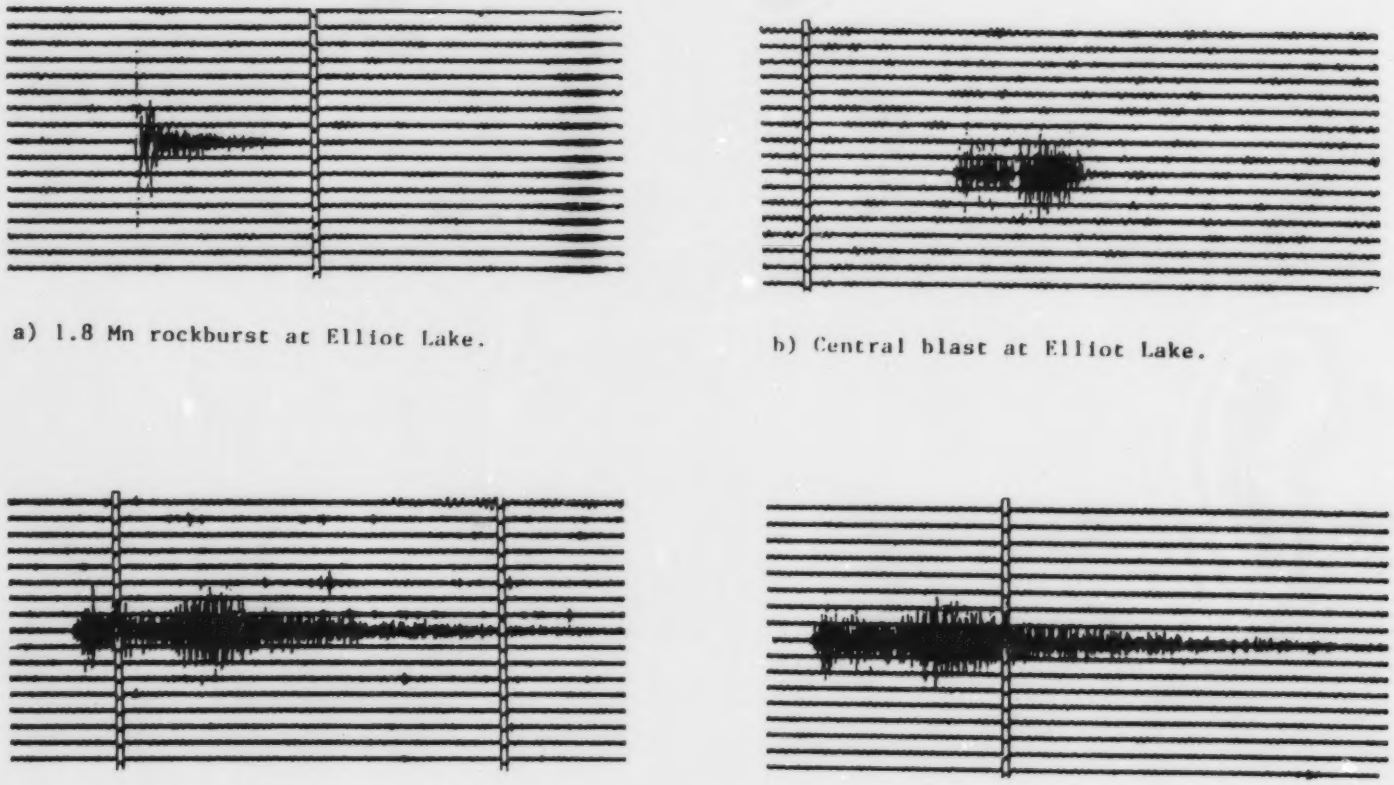


Figure 2 - Location of the seismograph stations around the Sudbury basin and data transfer of the original SLTN network (Hedley, 1992).



a) 1.8 Mn rockburst at Elliot Lake.

b) Central blast at Elliot Lake.

c) 2.9 Mn rockburst at Sudbury.

d) Blast at Sudbury.

Figure 3 - Analog seismic signals of blasts and rockbursts recorded on the Elliot Lake seismograph (Hedley, 1992).

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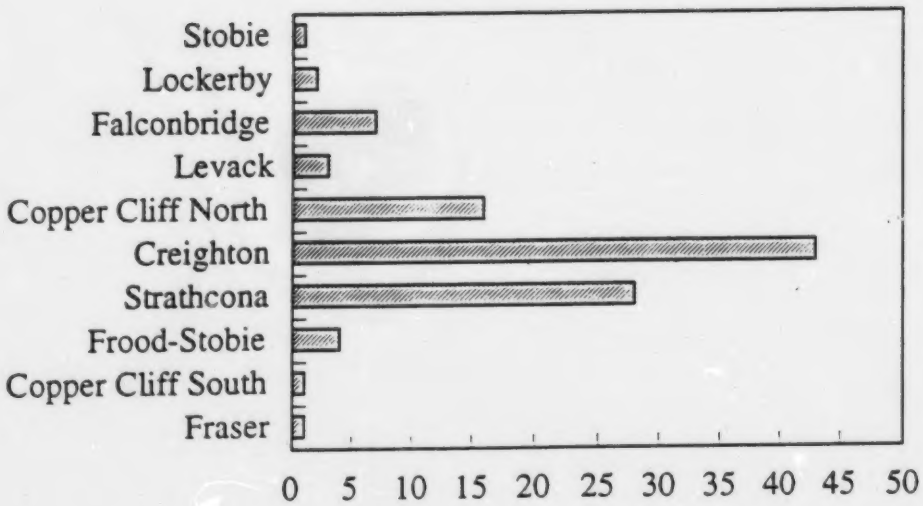

Figure 4 - Histogram showing the number of seismic events (Mn>2.0) in Sudbury mines during the period 1984-1990 (Talebi, 1993, data from Hedley 1992).

3.0 UPGRADING OF THE SLTN NETWORK

In 1991, the seismograph station network operated by CANMET in northern Ontario and eastern Quebec was reviewed and a proposal was made to upgrade this network (Mottahed, 1991). The intent was to use the more efficient "Remote Seismograph Digitizer" stations , such as those supplied by Nanometrics Inc. of Ottawa, instead of the conventional systems being used at the time. The main objective of this changeover was to improve the capabilities of this network and to make it more efficient. This was also compatible with the plans by the GSC to modify the Canadian National Seismograph Network (CNSN) in a similar manner. The following describes the objectives of the changeover planned:

- To keep directing the data from the three 1-component stations of the original SLTN network installed around the Sudbury basin to the central acquisition unit in Science North in Sudbury.
- To convert the Elliot Lake analog seismograph into a digital seismograph with the data being transferred to Science North to be merged with the data from the original SLTN seismograph stations.
- To install a three-component seismograph station within the Sudbury basin with the data being transferred to Science North to be merged with the data from the original SLTN seismograph stations.
- To increase the sampling rate from 60 Hz to 100 Hz for a better data quality.
- To proceed with data processing and magnitude determinations at the CANMET Elliot Lake Laboratory. This modification alone made possible a significant saving on the cost of dedicated telephone lines formerly used for data transmission to Ottawa.
- To plan the conversion of the analog stations at Red Lake and Kirkland Lake into digital seismographs, with the option of continuous transmission being postponed to a later date.
- To utilize the state of the art in computer and digital technologies, with improved analysis and communications software capabilities.

Table 1 shows a summary of the improvements made as a result of this changeover. Due to the relocation of the MRL staff from Elliot Lake to Sudbury in the course of

1993, the final destination of the data and the processing unit was changed to the CANMET Sudbury Laboratory.

Installation of the upgraded SLTN started in July 1993 when CANMET-MRL Sudbury laboratory took over the operation of the Sudbury local telemetered network. The upgraded SLTN at the time being consists of five seismograph stations (including Elliot Lake) with 7 components in total (four 1-component and one 3-component sensors), covering the Sudbury basin and Elliot Lake mining districts (see figure 5). The triaxial station located in the Dowling area is composed of 3 orthogonal sensors: 1 in the vertical direction and 2 in the horizontal plane (1 north - south and 1 east - west).

Table 1 summarizes the improvements made as a results of the upgrade. These can be summarized as following:

- Increased sampling rate for a better quality of digital data
- Improved event detection and location capabilities
- Cost reduction for data transfer since processing done at Sudbury
- Full-time supervision and maintenance
- An increased number of sensors for a better source location accuracy
- A three-component sensor providing better coverage and data available for in-depth research studies
- Expansion capabilities for the future across Ontario and Quebec
- Improved data quality, data analysis and communications software capabilities

Table 1 - Comparison between the original and the upgraded SLTN systems.

	Original SLTN	Upgraded SLTN
Operation period	1987-1993	1993-present
Sampling rate	60 Hz	100 Hz
Sensors	Three 1-component	Four 1-component One 3-components
Detection level	1.5 Mn	< 1.5 Mn
Data processing	GSC-Ottawa	CANMET-Sudbury Lab.

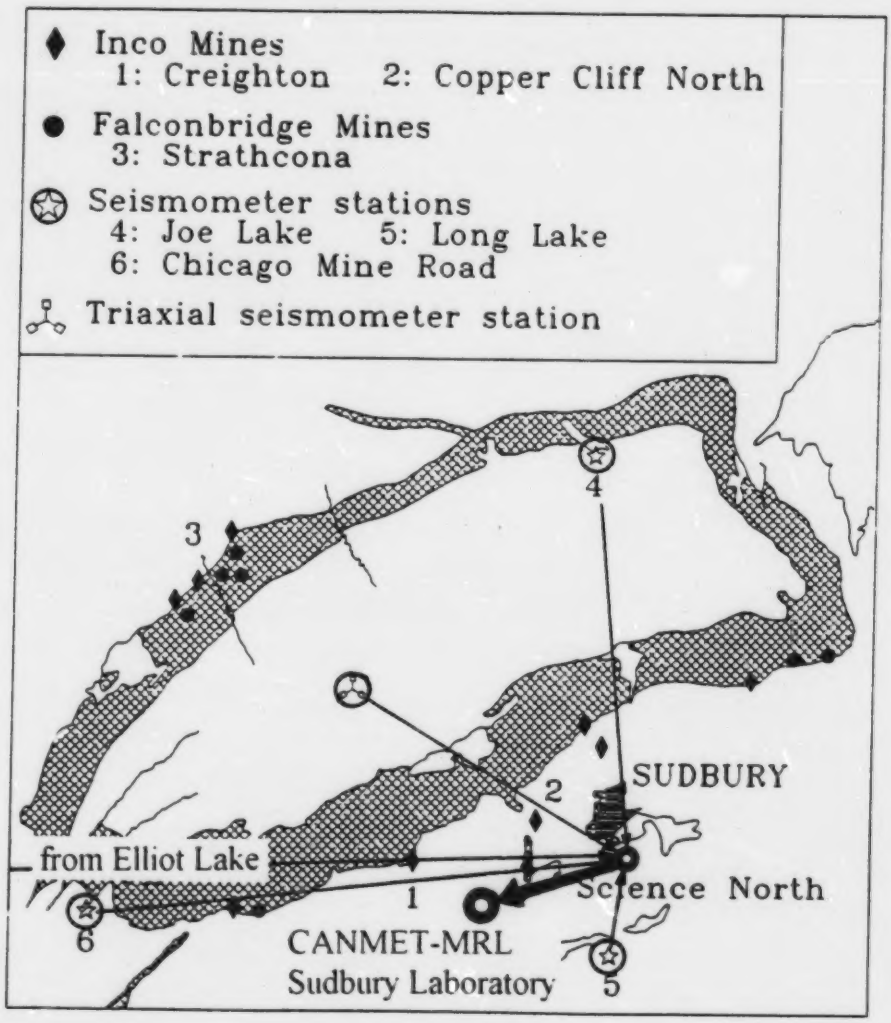

Figure 5 - Location of the seismograph stations and data transfer of the upgraded SLTN network. The Elliot Lake sensor site is not shown but is part of the network.

4.0 OVERVIEW OF THE SYSTEM

In this section, we provide the technical details of the upgraded SLTN network, as well as the procedures used for data acquisition and processing. Figures 6 and 7 show schematic procedures for data transfer and data processing.

4.1 Hardware

All sensor sites use single-component, one-second period, Teledyne Geotech S13 seismometer units which are used in numerous seismological applications around the world. The vertical and horizontal sensors used in the network consist of a single component, short-period seismometer located on surface in a sealed vault. Each sensor operates with a minimum detectable ground motion of 2 nm/s (nanometers per second). This resolution is equivalent to the amplitude of a magnitude 1.5 Mn event located at 100 km distance. The frequency range of these sensors covers the 0.5 - 40 Hz range. These sensors are designed to operate reliably at temperatures down to - 40° C. The analog signals generated by the sensors on site are then filtered and converted to digital signals using an RD3 100 Hz digitizer. The continuous digital signal is then sent via highspeed modem and dedicated phone lines to Science North in Sudbury.

The communications processor package consists of several hardware and software components. At Science North, 4 dedicated high speed modems receive data from remote sensor sites and transfer them to a Front-End Processor (FEP). Each FEP is then linked to the communications processor which is configured specifically for seismograph operations. The processor is responsible for the reception and decoding of incoming data and the trigger detector information. A Global Position Satellite (GPS) master clock is used to link all the incoming data in real time, with an accuracy to 4 decimal points. A software program called Network AQuisition Software (NAQS) is the primary data acquisition program which runs the host computer at Science North. Any triggered event is simultaneously stored in a large ring buffer or hard disk partition on the main acquisition computer. The event data are then transferred from Science North to the CANMET-MRL Sudbury laboratory on Kelly Lake road for detailed analysis.

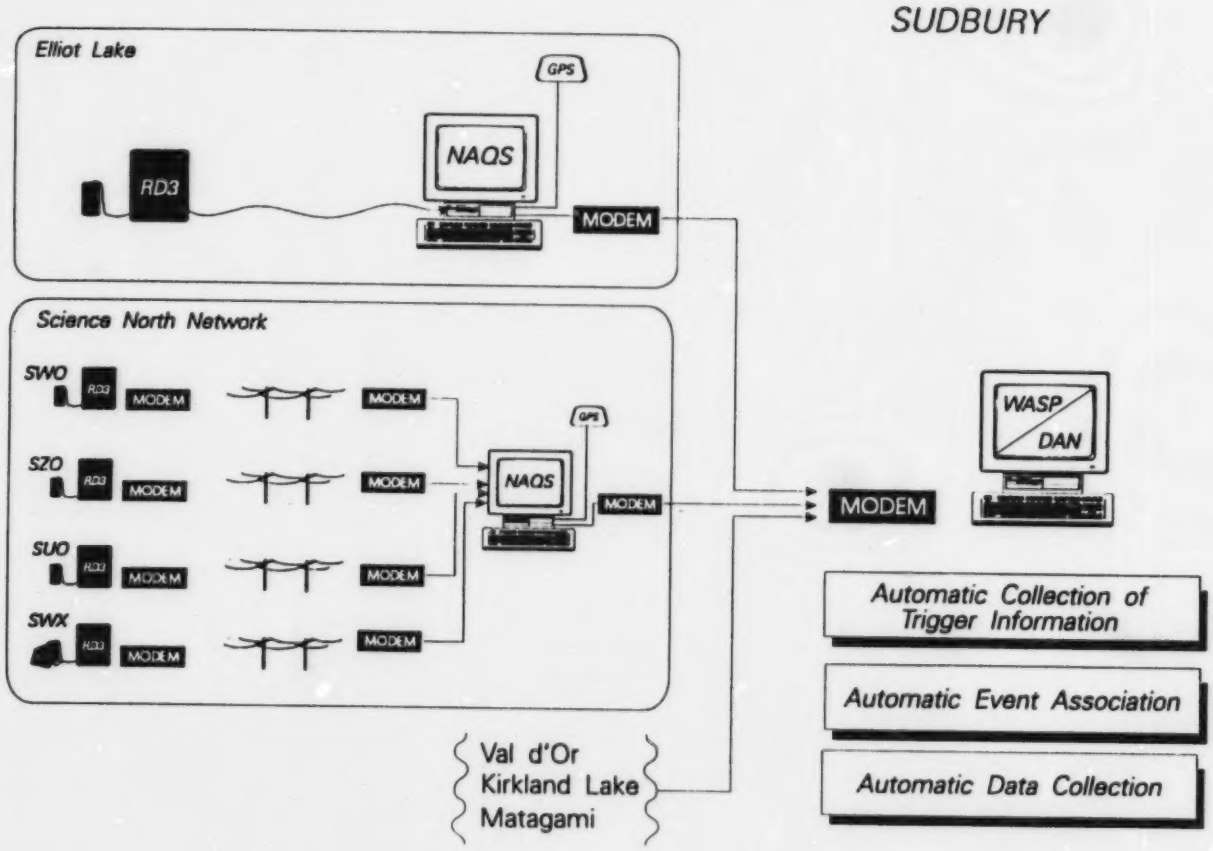

Figure 6 - Schematic diagram of data transfer procedure of the upgraded SLTN (Courtesy of Nanometrics Inc.).

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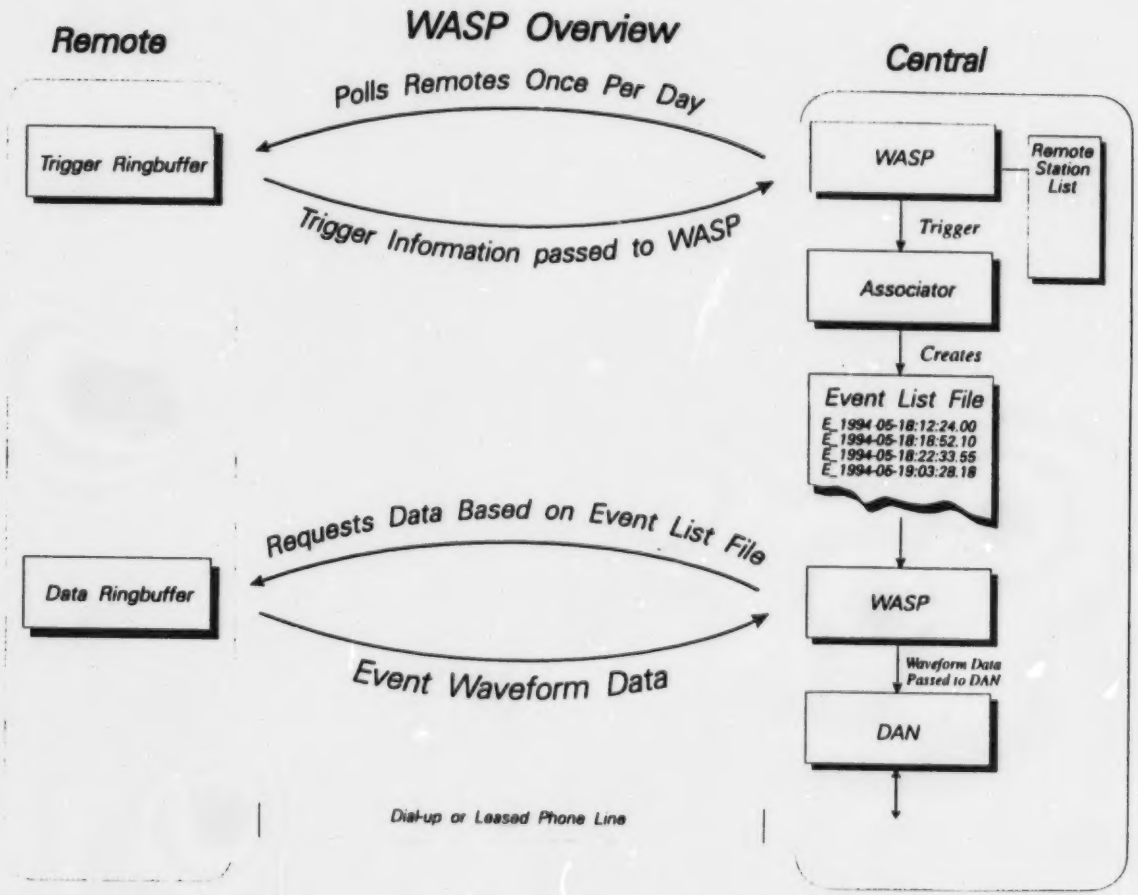

Figure 7 - Schematic diagram of data processing procedure for the upgraded SLTN (Courtesy of Nanometrics Inc.).

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4.2 Software

The Wide Area Seismic Program (WASP) is the software package to be operated from a central station for automatic data transfer from individual seismograph stations. Dial up messages requesting data on triggered events is sent out from the central station to remote sites which then send the requested data to the central computer for processing and analysis. The changeover from the previous system to the automatic procedure over the past year has been time consuming and the operation of this software has not been a matter of routine. However, the recent completion of this procedure was a major improvement, at the leading edge of the technology, and will help save considerable time since manual handling of the data would be virtually eliminated and calls can be completed in 'off- peak hours' . The operational WASP allows for dial ups to be completed automatically, the data to be stored on the computer and be ready for review and processing first thing in the morning.

4.3 System calibration

During the initial installation and network setup, Nanometrics Inc. performed a system calibration to determine the frequency response of the system. This calibration demonstrated that SLTN sensors were responding to the generated signals well within the expected frequency band determined by the manufacturer (0.5 - 40 Hz). A calibration in a broader frequency range (0.5 - 100 HZ) was also performed on the Elliot Lake sensor by CANMET-MRL personnel to determine the response of the seismograph station used for magnitude determinations. This comprehensive type of calibration will be performed in the near future on all the seismometers currently part of SLTN. This information is also used by the response file, which is in turn used by the event source location code.

4.4 Daily procedure

The events recorded by the host system at Science North are transferred via dedicated phone lines to the CANMET Sudbury laboratory on Kelly Lake Road in Sudbury. Once the event trigger files are collected, a review of each event is completed. These events are classified into 4 categories:

- Blasts: related to mining and construction activities (figures 8 and 9),

- MIS events: Mining Induced Seismic events confirmed by mine operators, either using an operating microseismic system in the mine or by underground observations (figures 10 and 11),

- Possible events: Events neither recorded on a microseismic monitoring system, nor felt by mine operators in the absence of such a system at the mine,

- Global events: Large-scale high-energy distant teleseisms from outside the Sudbury basin (figure 12).

If the event trigger is classified as MIS, the following steps are completed:

a) P- and S-wave arrival times are determined for each sensor site and the source location algorithm is used to determine the event source location based on P- and S-wave arrival times. Events within the SLTN array are the most easily and accurately located.

b) The Elliot Lake remote site (ELL) is linked to the network via modem and the data are extracted for the same time window as the event within the SLTN. The average P wave travel time for an event coming from the Sudbury area to trigger the Elliot Lake sensor is about 14.5 Sec. The ELL and SLTN files are then merged and magnitude determination is completed.

c) The final product is a location plan showing the triggered sensor sites, the events source location in global coordinates and the magnitude of the event. An example is shown on figure 10.

The location of the event is confirmed by mine operators provided there is an on-site microseismic monitoring system. The SLTN source location accuracy is then compared to the one from the on-site monitoring system. Epicenters, i.e. the projection of event source locations on surface, are typically determined with an accuracy of about 1.0 km. A printout of the event waveforms showing P- and S-wave arrivals is then completed. This information package could then be sent to the mine ground control department for their records if they request it. Also, the event and its associated parameters are added to the database on a spreadsheet. At the end of each week all the event data for that week are copied to an optical disk for permanent storage. A list of the MIS signals for each mine is also kept.

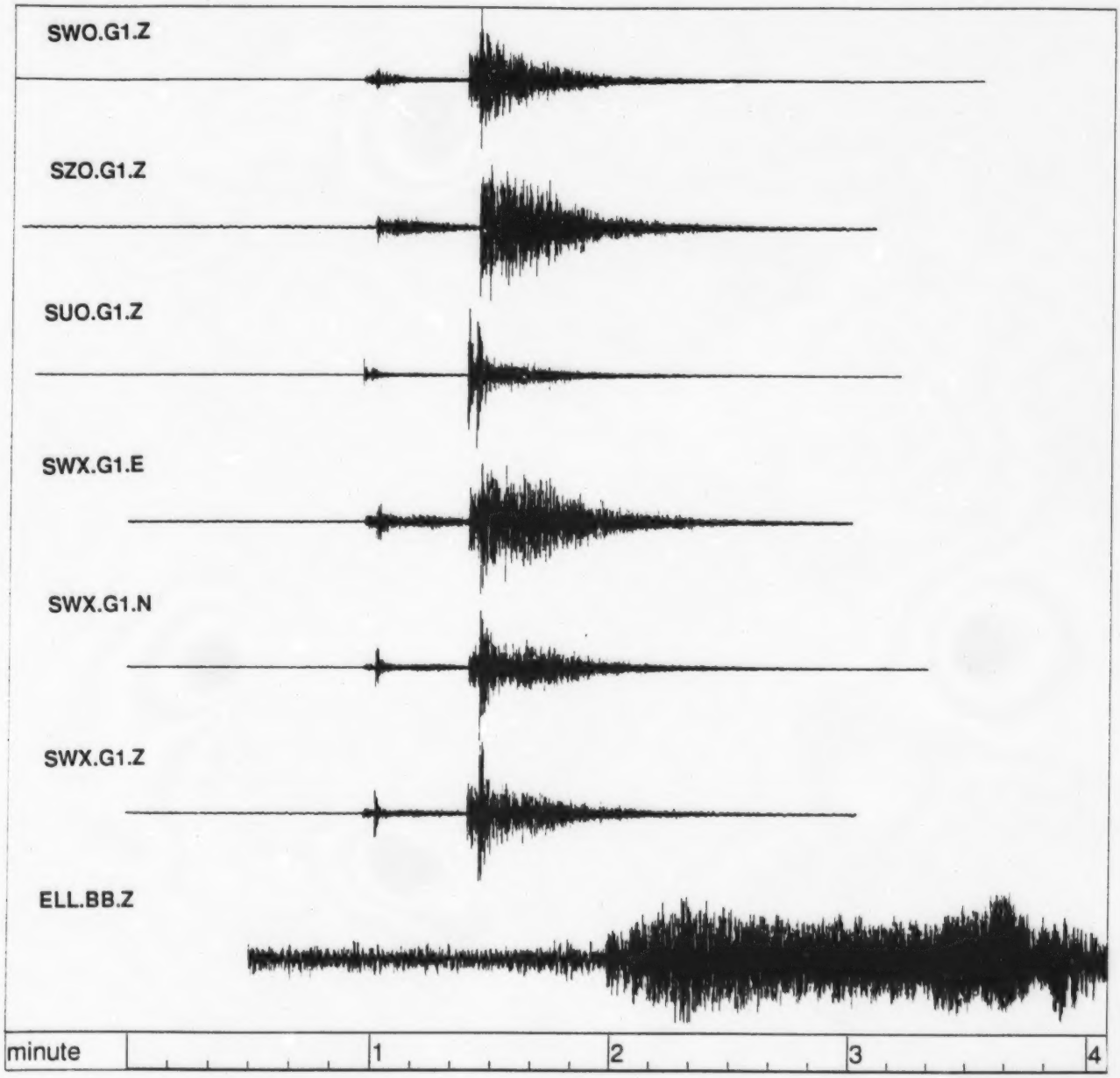


Figure 8 - Example of a blast signal recorded on the SLTN. Note the initial detonation of the blast causing the smaller signal, followed by the main production blast causing the larger signal to be recorded. The seismometer stations are as follows: Joe Lake (SWO), Long Lake (SUO), Chicago Mine Road (SZO), Wallace Road (3 components: SWX) and Elliot Lake (ELL).

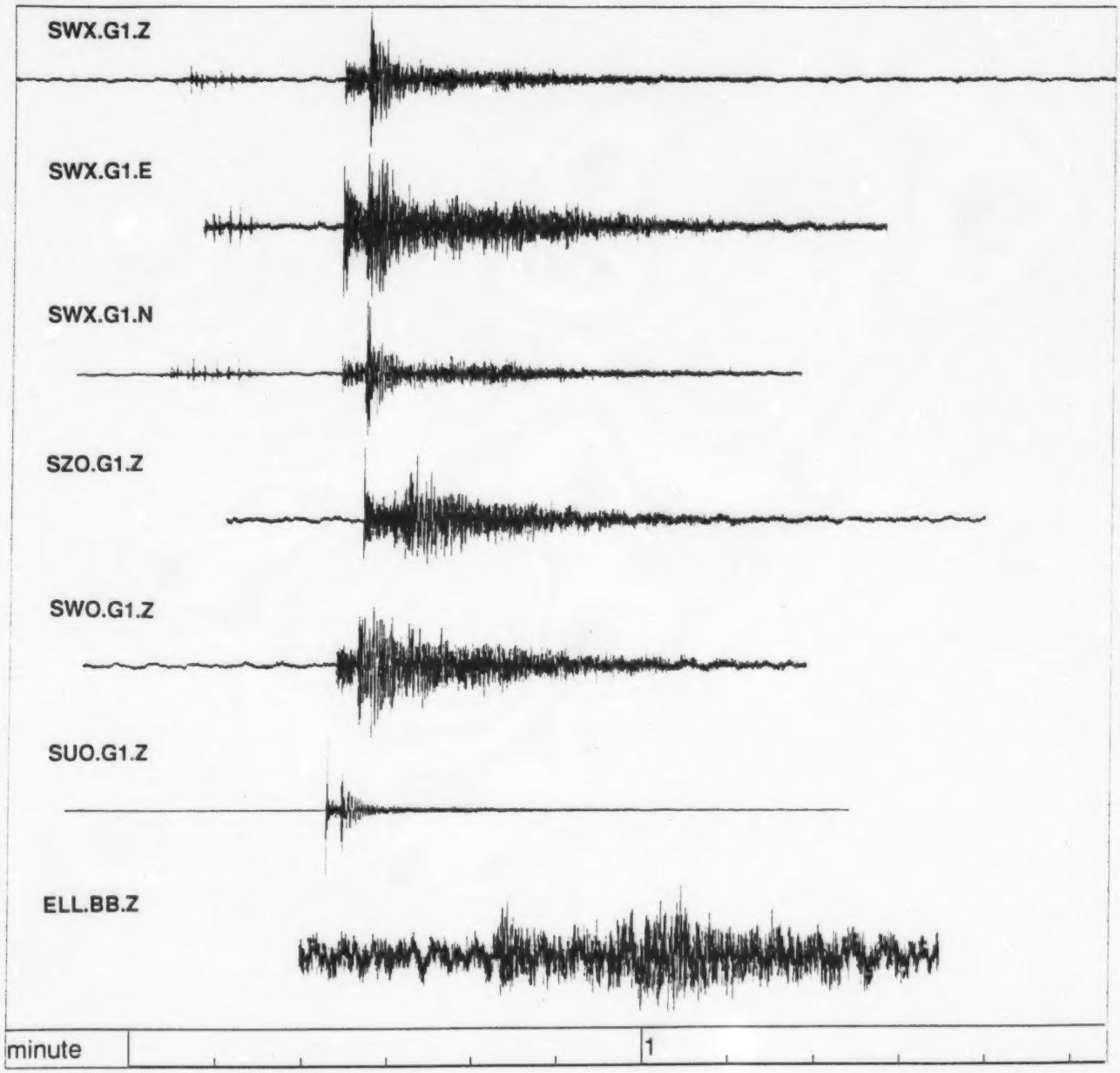
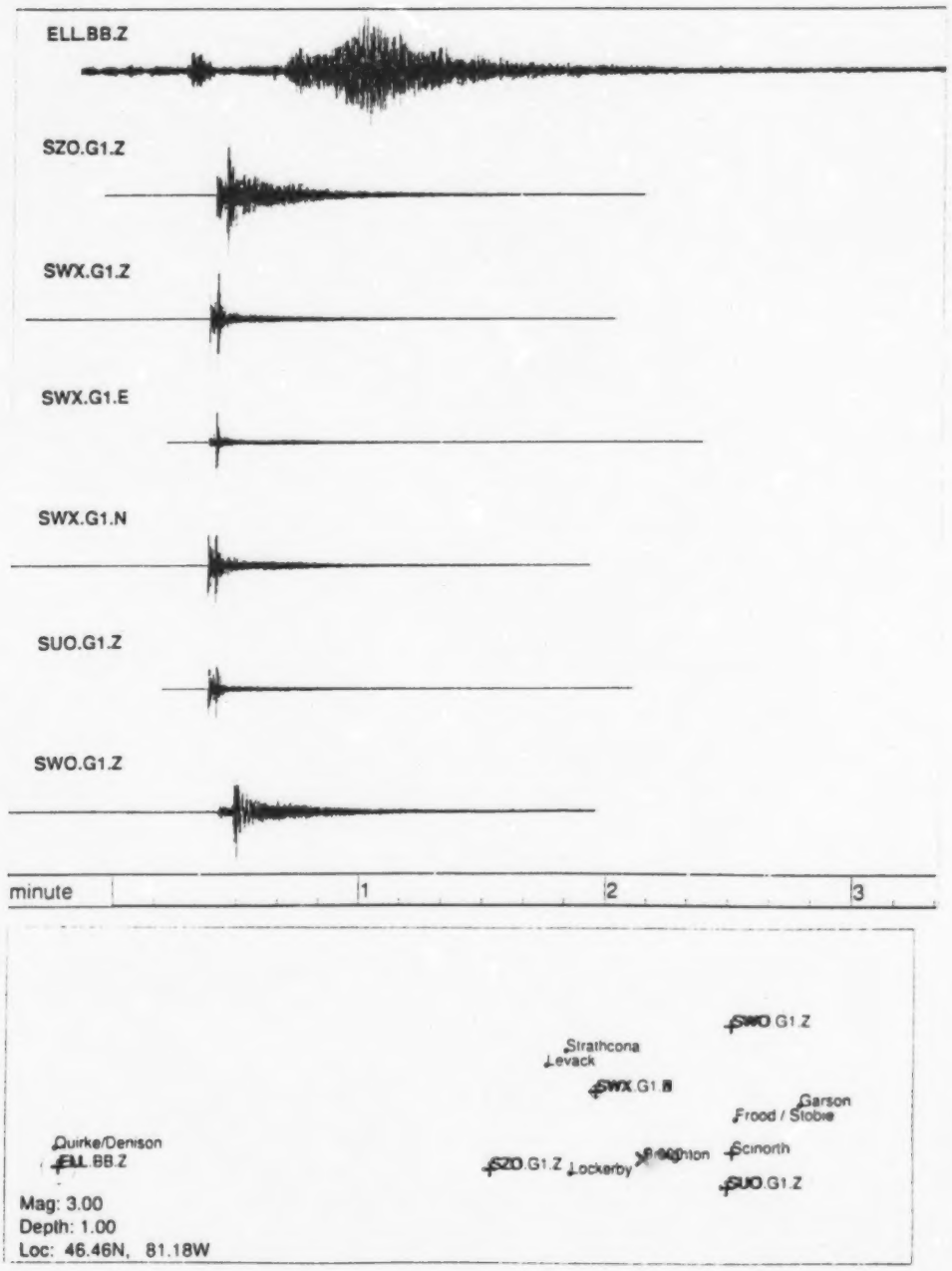


Figure 9 - Example of signals from a blast using long delays, followed by a mine-induced event.



Figures 10 - Example of a mine-induced seismic event from INCO's Creighton Mine, as recorded by the SLTN, with the associated source location plan.

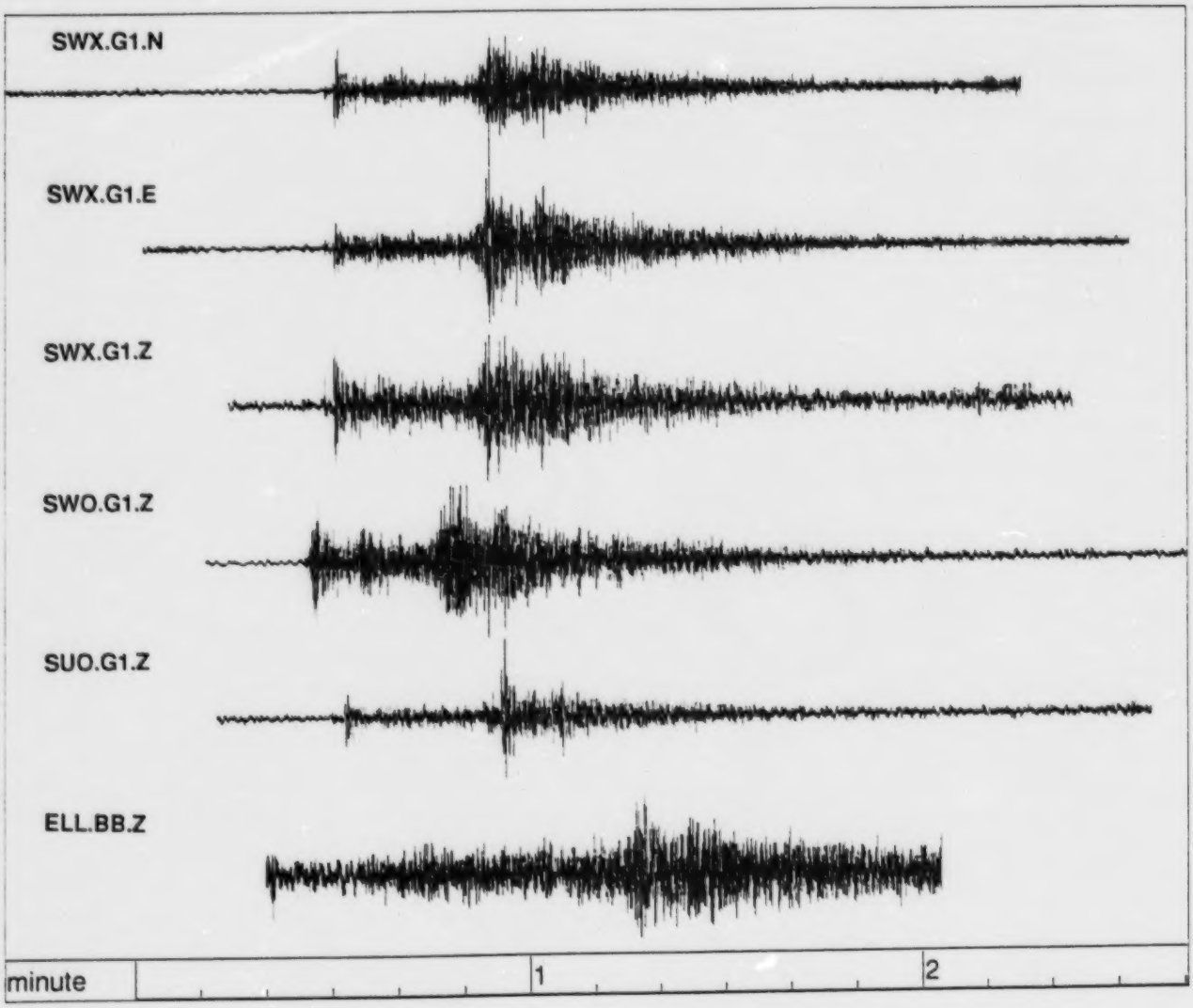


Figure 11 - Signals recorded by the SLTN for the Nov. 26, 1993 fatal rockburst at the Macassa mine in Kirkland Lake, Ontario.

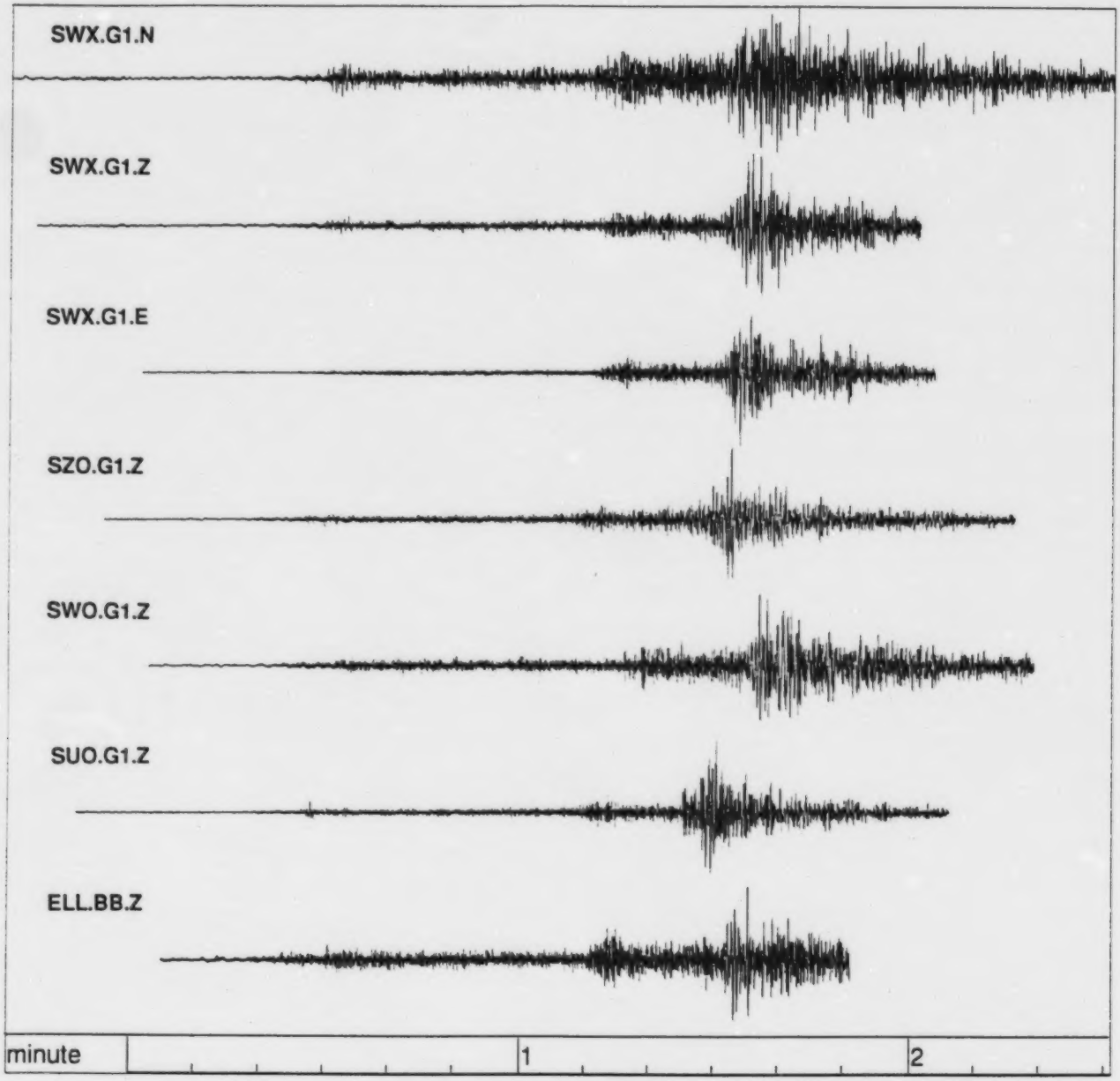


Figure 12 - Signals recorded by the SLTN in October 1993 for a magnitude 3.6 Mn earthquake in the south-western Quebec, Montreal area.

5.0 SUMMARY OF OPERATIONS

In this section, we provide a summary of the operations of the upgraded SLTN for the period June 01, 1993 to August 31, 1994. Table 2 shows a list of mine-induced events (Mn>2.0) in northern Ontario for the period July 93-August 94.

June 01 - August 13, 1993: At the beginning of this time period, the operation of the SLTN was transferred from the GSC in Ottawa to CANMET, Mining Research Laboratories, Rockburst Group in Sudbury, Ontario. During this time period, the initial installation of the 6 channel digital acquisition network, primary setup and trouble shooting was completed. No large rockbursts were recorded by the SLTN during this time period due in part to the amount of downtime of the network.

August 14 - September 30 , 1993: During this time period, the system was operational approximately 65% of the time. Downtime was a result of software, hardware and phone line difficulties following the installation of the network.

October 01, 1993 - January 15, 1994: During this time period, the system was operational approximately 80% of the time. Downtime was a result of the continuation of software, hardware and phone line difficulties. Historically the beginning of this period is one of the most seismically active periods of the year as previously mentioned. Several key mine-induced events were recorded by the SLTN during this period, such as the Macassa mine fatal rockburst of November 1993 (figure 10). Increased levels of blasting activity, in preparation for the 2 month winter shut-down, was recorded from all INCO mines within the district. Several moderate-size events were recorded by the network early into this period. The remainder of the shut-down period was rather quiet.

January 16 - February 17, 1994: Operational coverage was poor due to persistent problems with the updated software installed to automatically transfer data from Science North to CANMET Sudbury laboratory. Local seismicity for this time period was lower than expected, due in part to the 2 month INCO winter shut-down.

Table 2 - Large mine-induced seismic events (Mn>2.0) in northern Ontario mines for the period July 1, 1993-August 31, 1994.

Mine/Company	Date (mm/dd/yr)	Local Time	Universal time	GSC	SLTN
Falconbridge Ltd.:					
Onaping	01/07/94	22:21:03	03:21:03	2.5	2.6
Fraser	11/07/93	09:15:47	14:15:47	---	2.4
Kidd Creek	04/13/94	05:13:54	09:13:54	2.7	2.9
INCO Ltd. :					
Creighton	07/27/93	11:52:43	15:52:43	2.3	---
Creighton	07/28/93	14:33:04	18:33:04	2.4	---
Creighton	08/05/93	22:39:51	02:39:51	2.9	---
Creighton	08/07/93	21:18:36	01:18:36	2.2	---
Creighton	09/13/93	23:59:00	03:59:00	2.3	2.4
Creighton	10/12/93	16:19:54	20:19:54	2.4	2.6
Creighton	10/19/93	22:23:04	02:23:04	2.2	2.0
Creighton	11/05/93	03:43:21	08:43:21	2.3	2.3
Creighton	11/05/93	22:23:22	03:23:22	2.8	2.9
Creighton	12/02/93	12:36:13	17:36:13	2.5	2.2
Creighton	12/02/93	13:41:10	18:41:10	2.6	2.4
Creighton	03/31/94	08:11:08	13:11:08	---	2.2
Creighton	04/02/94	08:26:30	13:26:30	2.0	---

Table 2 continued.

Mine/Company	Date (mm/dd/yr)	Local Time	Universal time	GSC	SLTN
Creighton	05/14/94	12:59:35	16:59:35	2.6	2.6
Creighton	08/31/94	03:17:04	07:17:04	2.9	2.9
Frood	12/06/93	16:11:40	21:11:40	2.2	2.3
Frood	01/10/94	06:24:42	11:24:42	---	2.1
Kerr Addison:					
Kerr Addison	01/19/94	09:08:00	14:08:00	2.2	---
LAC Minerals:					
Macassa Mine	11/26/93	08:20:36	13:20:38	2.8	3.0
Macassa Mine	11/26/93	08:20:43	13:20:45	2.5	---
Placer Dome:					
Campbell Red Lake	03/23/94	22:09:26	03:09:08	2.3	---
Rio Algom - Denison:					
Quirke / Denison	10/04/93	08:14:30	12:14:30	---	2.1

February 17 - May 23, 1994: A new communications software was installed as part of the main structure of the automatic dial up communications software (WASP) being developed by Nanometrics Inc. Although necessary and planned in advance, this installation was not successful and caused significant delays in data transfer and providing a timely response to information requests by mining companies. The level of local seismicity was low due in part to the fact that for all INCO mines within the basin, mine production and development was coming back on to schedule following the shut-down period. The end of this period historically has been seismically active. This did not appear to be the case for this spring period

May 22 - August 12, 1994: Nanometrics installed the remainder of WASP, the software required to complete the automatic dial up and data transfer package. As a result of persistent hardware and software conflicts, SLTN was rendered almost inoperable in the automatic transfer of data. Although the SLTN was acquiring event data as usual, retrieval of this data had to be done manually, a tedious and time consuming task causing significant delays in delivering a timely response to requests.

August 12 - September 9, 1994: At the beginning of this period, due to persistent problems associated with the remote operation of the network at Science North, it was decided to relocate the main acquisition hardware from Science North to the CANMET Sudbury Laboratory. The processing and the main acquisition computers were sent back to Nanometrics Inc. for minor hardware repairs. The system was not in acquisition mode during this period due to hardware repairs and relocation of telephone lines from Science North to CANMET Sudbury lab.

September 10 - 21, 1994: The system was operational in acquisition mode during this time period. As a highlight of this period, two major mine-induced events originating from Creighton mine were recorded (see figure 10). The recent changes made to the network have made it possible to provide a more reliable and timely response to system difficulties in data acquisition and transfer should they recur. New EtherNet cards have been installed to enable easier communications between the acquisition and processing computers. The software for automatic data transfer (WASP) was tested during this time period.

It is interesting to note that the ELL sensor site and acquisition computer have worked for the last 2 years with less than 3 days total downtime. The Elliot Lake seismograph can still be reliably accessed to retrieve data for any significant events originating from the Sudbury basin. Magnitude calculations using the data of this seismograph station can be easily performed.

6.0 DATA AND REQUESTS

Over the past year, information has been exchanged frequently between the Geophysics Division of the Geological Survey of Canada in Ottawa and CANMET-MRL Sudbury Laboratory, primarily to compare magnitude determinations of the SLTN with those of the Eastern Canada Telemetered Network (ECTN). The results of the two networks are typically within the acceptable range of 0.3 Mn throughout the monitoring range of the SLTN.

The time period from mid-October to early December 1993 has been the most seismically active. Historically, this is one of the most seismically active periods of the year. However, the spring season which is usually a seismically active period proved to be rather quiet. On the whole, the past year revealed to be a relatively quiet year as far as seismic activity within the Sudbury basin is concerned.

Although SLTN has been designed for monitoring rockbursts and blasts within the Sudbury basin, it records some of the more significant large-scale global seismic events as well. Requests for information come from numerous sources including the GSC in Ottawa, contractors performing blasting operations for road construction and repairs around the Sudbury basin, and a concerned or curious public. As well, requests regularly come from media and Universities regarding significant local rockbursts, such as the Macassa Mine rockburst of Nov. 26, 1993 (see figure 11). A typical long distance teleseism or earthquake recorded by the network is the 3.6 Mn earthquake in the Montreal area, in October 1993 (See Figure 12). One of the most significant global events recorded by the SLTN was the 8.2 Mn deep-focus (640 km) earthquake of June 09, 1994 in Bolivia, South America. This particular event was widely felt in the northern hemisphere, even in northern Ontario. Reports regarding this particular event were directed to CANMET Sudbury laboratory from Elliot Lake, Espanola, and North Bay, Ontario.

7.0 FUTURE PLANS

The SLTN is currently ready for further expansion, should the need be there, to install up to 4 more seismograph stations around the Sudbury basin. Such an expansion will further improve the detection capabilities of the network. This could contribute to detailed site evaluation studies for new mining operations and monitoring blasting operations.

Future expansion of the network (see figure 13) will include linking the upgraded digital seismometers at the remote sites in Kirkland Lake, Red Lake, and the Val d'Or area of Quebec, to the SLTN. The completion of this work will ensure adequate coverage of the mining camps in northern Ontario and northwestern Quebec, and will improve the data base of mine-induced seismicity in these areas. More specifically, valuable information will be added to the database for the larger seismic events in the Sudbury area. This increased amount of data will broaden the base of the information available for rockburst research and allow for a better coverage and more accurate magnitude determinations. The expanded database will make it possible to investigate a number of research topics such as source mechanism of rockbursts and mine-induced seismic events, post closure seismic response of hard-rock mines, the effects of long term mining on regional geologic structures, etc.

It is planned to expand SLTN to include seismograph stations in Kirkland Lake, Ontario, Val d'Or and Matagami, Quebec in fall 1994. These three seismograph stations will form a sub-network monitoring rockbursts and mine-induced seismic activity in the other mining camps of northern Ontario and northwestern Quebec. A later expansion would include upgrading the seismograph station already in place in Red Lake, Ontario and the possibility of installing a new seismograph station in the Kidd Creek mining district.

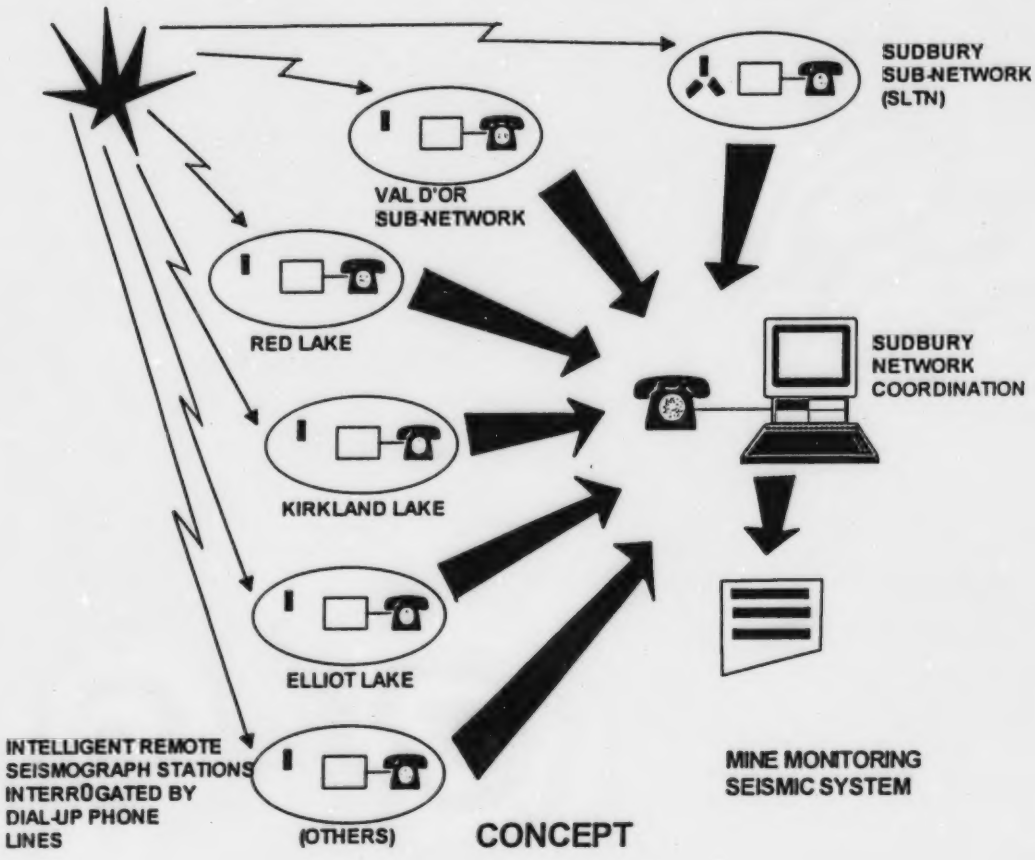


Figure 13 - Schematic diagram of the long-term objective of the expansion of the seismograph network in northern Ontario and eastern Quebec (Courtesy of Nanometrics Inc.).

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